3.3 Beaumont No. 1 Site

3.3.1 Propellant Mixing Area

A fuel slurry station and propellant mix station were operated at the Beaumont No. 1 site to process propellants and are shown as Buildings 317 and 315 on Figure 3-2 (grid M5 on Plate II). Building 315 was the principal mix station for the Large Solid Motor (LSM) program until its end in early 1966. The mix station was not used again until 1970 when it was reactivated as a back-up mixer for the SRAM program. During the SRAM program, this mix station was used every 6 months in order to meet USAF qualification requirements.

The slurry station (Building 317) was used during the LSM program to weigh and pre-mix the liquid ingredients. The mix station (Building 315) consisted of a 300-gallon mixer housed in a 40-foot-high building. The dry oxidizer was hoisted above the mixer and dropped in at a controlled rate while blades within the mixer blended it with the liquid ingredients. Building 319 was used for chemical storage. All mix station operations were controlled from a nearby bunker (Building 315-A) built into the side of a hill. The propellant mix cycle took about eight hours, including cleanup, which involved scraping and wiping down all containers and mixing equipment to remove any remaining propellant. Lockheed had detailed quality control and safety procedures established for propellant mixing and required these procedures to be followed precisely. Batches of propellant that did not meet specifications, as well as all cleaning materials (including the paper used for wipe down), were taken to a burn pit for incineration.

After processing, the thick, viscous propellant was poured under vacuum into insulated and lined metal casings. The cast propellant was then cured by heating it to 140°F for several days; curing resulted in a solid, rubbery mass bonded to the insulation. During the LSM program, casting and curing was done at a stand located a short distance to the south of the mix station (shown as Building 316 on Figure 3-2). During the SRAM program, the propellant was trucked to the Redlands plant for casting and curing. Photographs of the slurry station, the mix station, and the casting stand are included as Figures 3-3, 3-4, and 3-5.

Propellant formulas consisted of the dry oxidizer, liquid fuel ingredients, and burn rate modifiers. The oxidizer in use was ammonium perchlorate ($NH_4 ClO_4$), ground to a fine powder. It made up about 90 percent of the propellant by weight. All oxidizer grinding was done at the Redlands facility. The liquid ingredients consisted mostly of chemical derivatives of butadiene which produced propellants that cured to a rubber-like material. The burn rate modifiers were added last during the mixing process and consisted mostly of iron compounds. Ferrocene was used in SRAM motors. One modifier, Maloy blue, produced a bright blue propellant. The various propellant formulations differed mainly by the type of burning rate modifier that was used. Batches of inert propellant were also mixed by replacing the ammonium perchlorate with salt.

During plant closure in 1974, all usable parts of the mix station were dismantled and taken off-site to be sold. The concrete foundations of the mix and slurry stations remain today, as does the mix station bunker. A photograph of the mix station area as it currently exists is included as Figure 3-6. No adverse environmental impacts appear to exist at the propellant mixing area as a result of past activities. During all operational activities, it was required that the site be kept clean and that all propellant waste be taken to the burn pit for disposal.

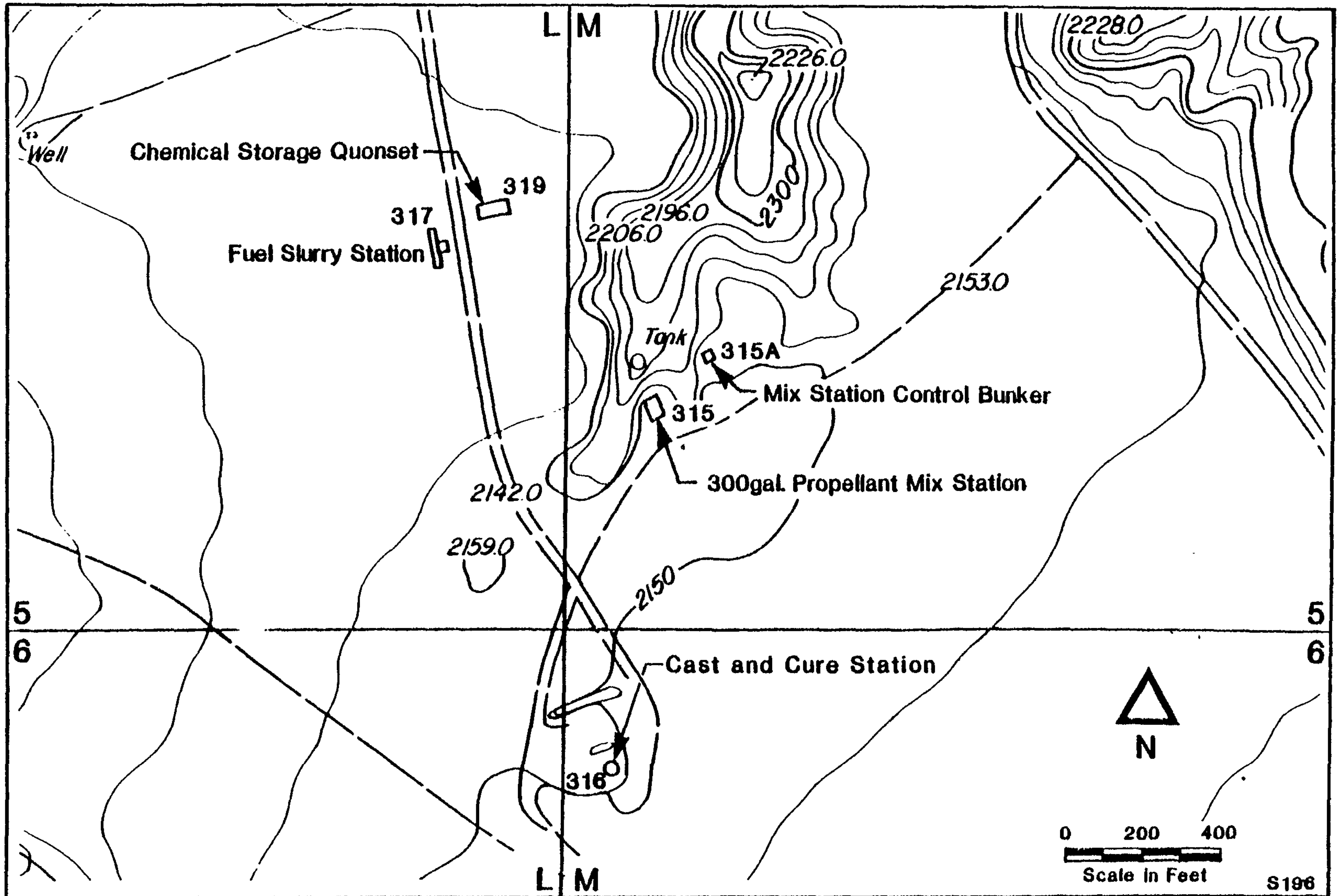

Figure 3-2. Beaumont No. 1, Large Solid Motor Program Propellant mixing area, used prior to 1966.

3.2 Overview of Solid Rocket Motor Production

The solid propellant rocket motors developed by LPC were simple units with no moving parts. The motors consisted of an encased energy supply which was a combustible mixture of all the elements required for the generation of propulsive energy.

The production of solid rocket motors by LPC involved several steps. First, the metal chambers that held the propellant were insulated, lined, and set up for casting. Next, the propellant ingredients were carefully weighed and mixed. The propellant then was poured (cast) into the metal casings. After casting, the rocket motors were cured and the propellant became a solid, rubbery mass bonded to the case insulation. Finally, the nozzle and igniter were installed. Throughout the manufacturing cycle of solid rocket motors by LPC, each part of the motor was thoroughly inspected, and each manufacturing process was carefully controlled and verified. Photographs showing the manufacturing process as conducted at the Beaumont No. 1 facility are shown in Section 3.3.1.

3.2.1 Motor Casings

The motor case served as a container for the solid propellant "grain" and provided a vessel capable of withstanding the high-pressure conditions produced by propellant combustion during motor operation. The case was usually part of the load-carrying structure of a rocket-powered vehicle. However, case pressurization loads during motor operation were typically somewhat greater than the structural loads. For this reason, pressurization loads usually governed the structural design of the case.

An optimum motor case design required high structural reliability, low cost, and low weight for the intended application. To attain this combination, high-strength steels were used, and very detailed structural analyses were performed. Before being loaded with propellant, each case was hydrostatically proof-tested to a pressure well above the motor operating pressure.

Solid propellant combustion produces flame temperatures in the range of 5,000 to 6,000°F, which is equivalent to the heat produced by an oxyacetylene cutting torch. To protect the metal motor case from this intense heat, an insulating material was applied to the inside surface before the propellant was loaded. Two insulation techniques were used by Lockheed, a rubber sheet molded and cured inside the casing, and a liquid mastic which was troweled in place. A properly insulated case could be refurbished and reused many times. In conducting the 156-inch-diameter Large Solid Motor tests, Lockheed reused some casing segments three times with no sign of damage or deterioration.

Once the casing was insulated, the surface of the insulation was lined with a rubber-based material. This liner was used to promote a strong bond between the insulation and the propellant. After lining, the casing was transported to a large oven where it was partially cured. The propellant was later cast against the lined surface and final curing of the propellant and liner was performed simultaneously. The result was a strong, intimate bond between the propellant and the case insulation.

3.2.2 Propellant Ingredients

The solid propellants used by LPC were classified by government and military agencies as nondetonating materials. They consisted of fuel (polymeric binder and aluminum), oxidizer, and burn rate modifier. Ignition of the fuel and oxidizer mixture generated heat and pressure which continued until the grain was consumed. The burn rate modifier helped to control the rate of combustion.

Before being mixed with the oxidizer, the fuel and burn rate modifier ingredients were weighed and formally accepted for use. Weighing was carefully conducted and verified to help ensure that each of the propellant batches met required specifications and had near identical properties. The fuel and modifier ingredients were premixed as a fuel slurry before being transported to the propellant mix station.

Solid propellant combustion required such large amounts of oxygen that there was much more oxidizer in propellant than fuel. The most widely used oxidizer was ammonium perchlorate, a colorless, crystalline salt. Two forms of ammonium perchlorate were used: ground and unground. The ground material was processed in special equipment until each particle of the oxidizer powder was precisely reduced to a size of 6 to 8 microns. (One micron is equivalent to 40 millionths of an inch.) The average particle size for the unground material was 200 microns. The ground and unground materials were weighed and used in the propellant in precise proportion to each other. Oxidizer proportions and particle sizes were precisely controlled because they had a profound effect on propellant burn rate.

3.2.3 Propellant Mixing

A large vertical mixing machine was used to combine the fuel slurry and oxidizer into a homogeneous fluid. Propellant ingredients were transported to the mixer in special containers that discharged into the mixing bowl upon command from an operator stationed in a remote control room.

The mixer was equipped with a jacket that circulated heated water around the mixing bowl. The heat transmitted by the jacket kept the viscous propellant mix in a free-flowing state. In addition, the mixer blade action included swirling, agitating, and scraping motions to ensure uniform distribution of the propellant ingredients. Vacuum was used to prevent the incorporation of air bubbles in the propellant during mixing. The remotely controlled mixing operation was continuously monitored by video cameras as well as by temperature sensors at selected locations on the mixer. Mixing was initiated by adding the oxidizer to the fuel slurry at a programmed rate. After a final vacuum mix, the propellant was ready for casting.

Many separate propellant batches were mixed in the 300-gallon mixer at the Beaumont No. 1 site to provide the hundreds of thousands of pounds of propellant needed to cast a Large Solid Motor segment. To ensure that properties of each batch were identical within the necessary limits, quality control tests were performed on samples from each batch before it was cast.

3.2.4 Cast and Cure

The casting operation consisted of pouring the propellant into the rocket motor casing. The LSM was cast one segment at a time, while Short Range Attack Missles (SRAM) motors were cast in clusters of two or three. Casting was done under vacuum to allow the propellant to set into a uniform, void-free mass. LSM's were cast at the Beaumont No. 1 site, but propellant mixed for SRAM motors was transported to the Redlands facility for casting.

Once the motor was positioned at the casting site, it remained there throughout the subsequent curing operation. Curing consisted of heating the cast propellant to 140°F for appropriately six days. At the end of cure, the propellant became a solid, rubbery mass (the grain) bonded to the case insulation which, in turn, was bonded to the metal case wall.

3.2.5 Assembly

After curing was completed, the rocket motor was allowed to cool at a programmed rate before being transported to an assembly site.

Assembly of the LSM's was conducted at the Beaumont No. 1 site and included installation of the igniter, stacking and joining the segments, and installation of the nozzle. The nozzle formed the outlet for propellant combustion gases and was an important mechanism used to increase the thrust of the rocket motor at least 50 percent over a nozzleless hole. The ignitor for the LSM was a complete solid rocket motor in itself. The igniter translated an electrical firing command signal into complete combustion of the propellant grain burning surface. This translation of energy forms was accomplished by a pyrotechnic device called a squib, which was contained within the igniter. The squib received the electrical energy of the firing command signal as input and produced heat and flame as output. As a safety measure, the squibs were not installed until the motor was ready to fire.

Assembly of SRAM motors included installation of the nozzle, head-cap, raceway, and electrical systems. This was conducted at a Building 250, located at the Beaumont No. 2 site.

3.2.6 Inspection

The same types of inspection techniques were common to all solid rocket motors regardless of size. Principal among these was a class of techniques known as nondestructive testing (NDT). Included in this class were x-ray, ultrasonic, magnetic-particle, and dye-penetrant, as well as other methods. LPC routinely performed all major types of NDT. The LPC NDT equipment included one of the largest industrial x-ray facilities in the country, a 25-million electron volt (MeV) Betatron unit located at the Beaumont No. 1 facility.

Throughout the manufacturing cycle of solid rocket motors by LPC, each part of the motor was thoroughly inspected, and each manufacturing process was carefully controlled and verified. Formal documentation was prepared to record the history of the component and process and to serve as an authorization for acceptance. After acceptance of a motor, based on its history of inspection by the appropriate techniques, it was ready for test or delivery.